

propulsion

The future of
***advanced
propulsion***

is at

NASA
Marshall Space
Flight Center



Propulsion technologies we need to reach the stars are the engines that drive America's future.

Innovative research and development (R&D) in advanced propulsion systems are essential for space transportation to extend to the farthest reaches of the space frontier.

Powerful, efficient propulsion systems, combined with new weight-saving, durable materials, reduce the costs of putting payloads and people into orbit while increasing safety and reliability.

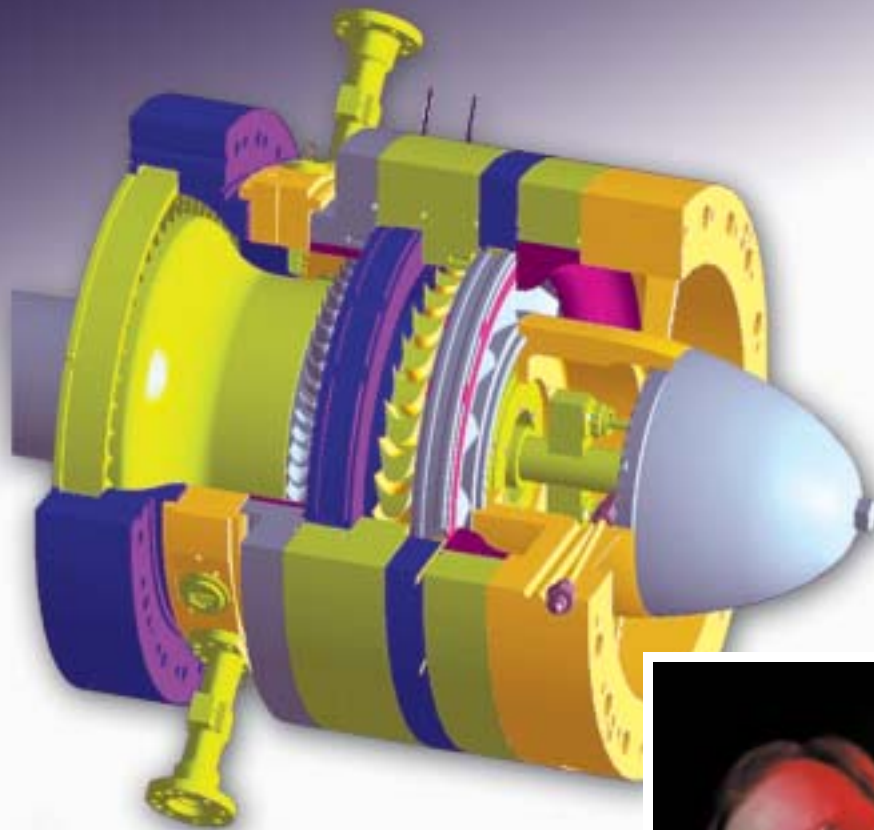
Marshall Space Flight Center leads NASA's efforts in space transportation systems development.

We have unique expertise to help devise cutting-edge propulsion and transportation systems. We also have invested millions of dollars in acquiring and developing the capabilities and facilities needed to design, develop, and test these new propulsion systems.

We invite you to partner with Marshall to develop new propulsion systems, learn from our experience, or benefit from our comprehensive facilities. This information booklet describes our expertise and facilities in the following propulsion areas:

- Research and concept development
- Modeling, analysis, and design
- Propulsion testing





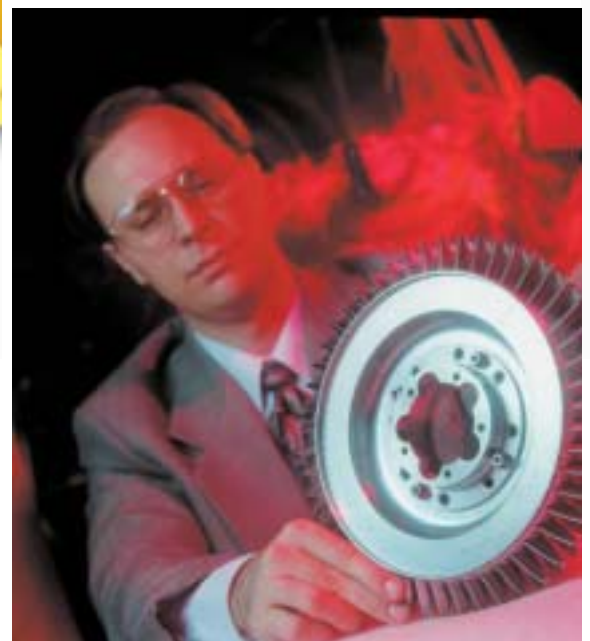
Cooperative Efforts Benefit NASA and Industry

In an effort to achieve performance improvements with Space Shuttle main engine turbine components, Marshall Space Flight Center undertook an experimental investigation in partnership with Pratt & Whitney, manufacturer of the Shuttle's high-pressure fuel pump. This team approach to research yielded significant benefits for both Marshall and Pratt & Whitney.

Working together, Marshall and Pratt & Whitney engineers conducted various experiments to monitor the flow of hot combustion gases through the turbines in various alignment configurations. These experiments showed that rotors and stators could be adjusted for a significant improvement in Shuttle efficiency. Pratt & Whitney engineers later applied these data to the PW-4084 engine for the Boeing 777, improving engine efficiency 0.5%, saving hundreds of gallons of fuel on transoceanic flights and millions of dollars for U.S. airlines.

The success of this partnership prompted another cooperative project—this one for turbine optimization. A team of experts in turbine aerodynamic design and analysis, mechanical design, structural mechanics and dynamics, rotordynamics, and turbine testing was formed with participants from Marshall, Riverbend Design Services, Boeing/Rocketdyne, Battelle/Florida Turbine Technologies, Allied Aerospace Industries, Kulite Semiconductors, the University of Florida, and Oxford University.

These are just two examples of how cooperative efforts can benefit NASA and commercial companies and universities. We invite you to contact us to discuss partnership opportunities.





A Commitment to Collaboration

Many of the significant advances in propulsion have been based on team-based research. From Dr. Wernher von Braun and his colleagues to the partnerships under way today, effective research is a collaborative process.

Marshall Space Flight Center brings together government, industry, and university researchers to define the future of advanced propulsion:

- Government researchers provide insight into future directions. By performing high-risk, high-payoff research, Marshall's staff can progress by leaps and bounds. They also maintain a focus on NASA's needs—and by extension the needs of the American people—integrating their research efforts with those of our industry and university partners.
- Industry researchers are a crucial element to Marshall's efforts. They ensure that the work done to meet NASA's needs will have relevancy to users in the private aerospace industry. They also facilitate the transition of technology from NASA to the private sector.
- University researchers provide a fundamental perspective that is essential to successful technology development. By leveraging academic talent, the research team brings together the best and the brightest. Academic researchers also have a valuable role for the future, as their participation in Marshall's research will enhance the education process for advanced propulsion.

Designed to spark new opportunities for collaborative research, this booklet provides information on Marshall's advanced propulsion research areas and capabilities.

DEVELOPMENT



Advanced propulsion begins with research and concept development. Such work yields new launch systems to place payloads and people into orbit safely, simply, dependably, and at a low cost. It also allows us to begin exploring the farthest reaches of our solar system and beyond. Researchers working together with Marshall and its unique facilities can combine their expertise to research and develop innovative propulsion concepts and technologies.

Reusable Launch Vehicles (RLVs)

The Space Shuttle—which has had unparalleled success—represents only the beginning of what is possible for RLVs. Having learned many lessons from this first-generation RLV, Marshall researchers are now developing lower cost and safer second-generation RLV propulsion elements:

- Highly reliable and highly operable main engines
- Advanced and innovative approaches to propellant systems
- Propulsive control systems using environmentally friendly propellants
- Miniaturized, highly reliable sensors
- New materials for the harsh environments internal to rocket engines

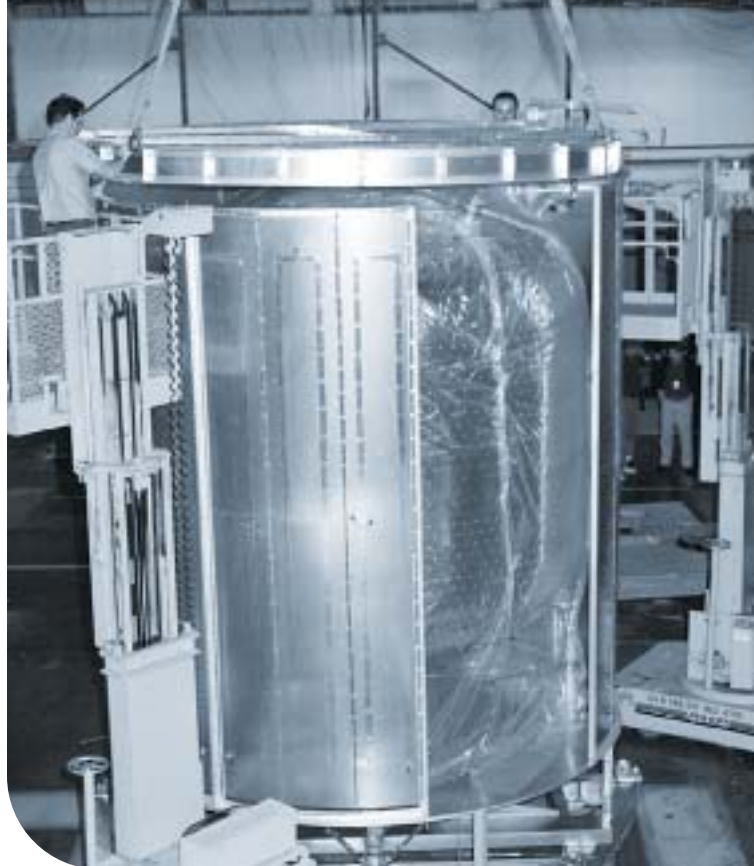


Air-Breathing Rockets

Marshall has been developing and testing air-breathing rockets for several years. Also referred to as rocket-based combined cycle (RBCC) engines, these vehicles get their initial take-off power from air-augmented rockets that boost performance about 15% over conventional rockets. Once the vehicle's velocity reaches Mach 3, the engine converts to ramjet and then scramjet modes around Mach 5, relying totally on atmospheric oxygen to burn the fuel. Once Mach 10 is achieved, the engine reverts to a conventional rocket-powered system, propelling the vehicle into orbit.

Cryogenic Fluid Management

Cryogenic propellants are stored at temperatures as low as -430°F (-221°C) and offer an ideal source of power for moving beyond low-Earth orbit. Such chemicals offer high performance via their high specific impulse (I_{sp}) and high density impulse. In an effort to make cryogenic propellants a reality for these applications, Marshall researchers are actively pursuing long-term storage technologies as well as technologies for acquisition and quantity gauging in the low-gravity environment of space. In addition to extensive R&D capabilities, Marshall offers world-class cryogenic test facilities for large-scale system testing, including small-scale component, instrumentation, and material property calibration laboratories (see pages 22–27).



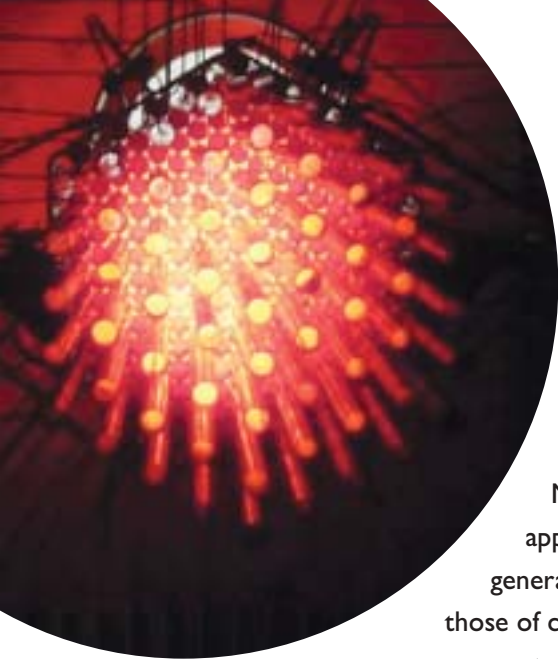
Advanced Propellants

New propellants with higher density, less toxicity, and better performance than existing propellant combinations are needed to reach NASA's space transportation goals.

Marshall is evaluating high-energy synthesized hypergolic propellants that could be used for future satellite station-keeping and orbital-maneuvering systems. These storable high-energy fuels provide better volumetric efficiency than traditional hydrocarbons and safer ground operations than non-hydrocarbon hypergolic fuels.

Gelled hypergolic propellants show promise of accommodating larger temperature extremes and producing better impulse density than liquid hypergols. These gelled propellants yield benefits for planetary mission application where low mass and packaging minimization are paramount, such as surface-to-orbit return vehicles.

Other exotic hydrocarbon compounds such as quadricyclane, metallic hydrogen, and competitive impulse noncarcinogenic hypergol are being examined.



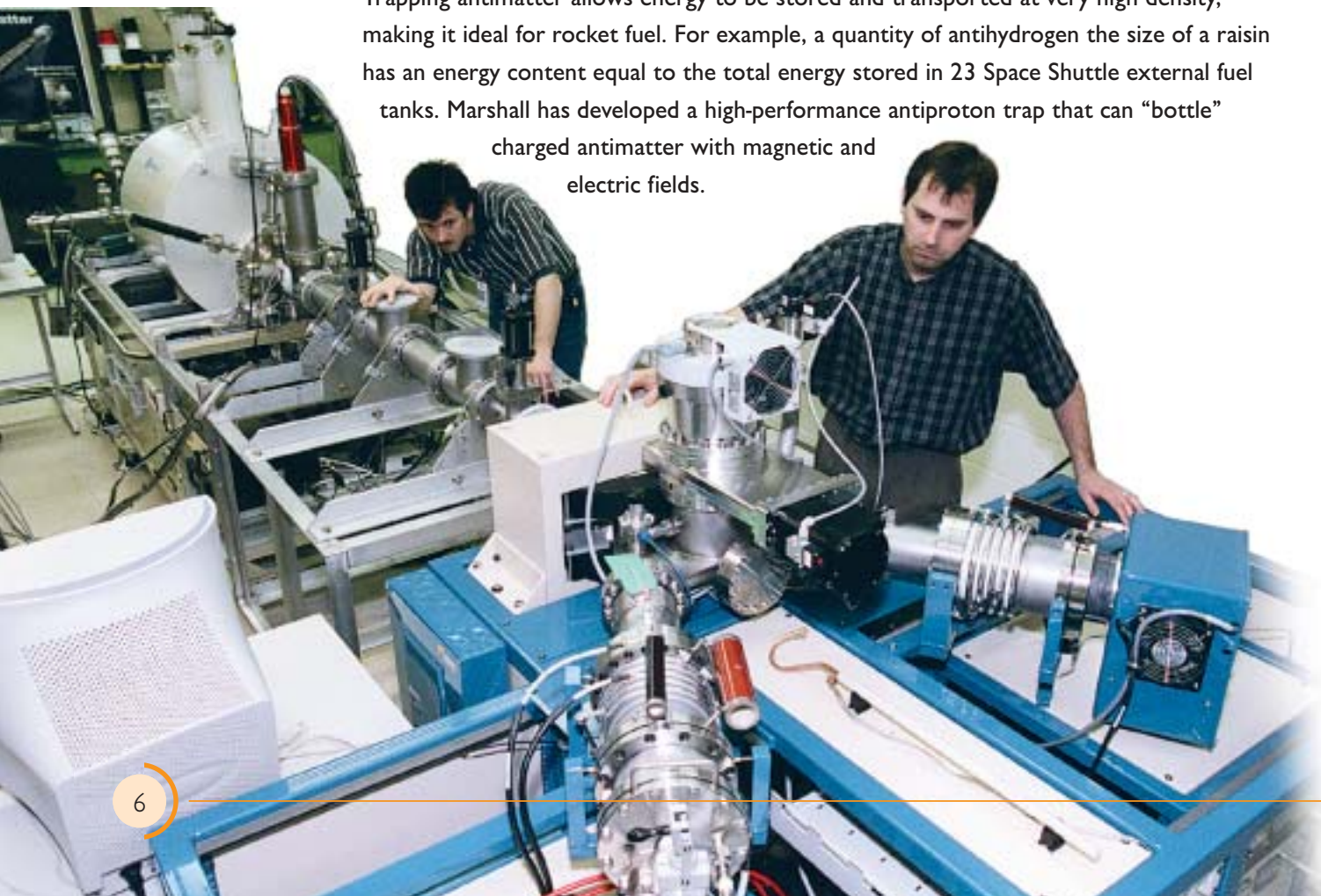
Nuclear Electric Propulsion

Marshall is using innovative non-nuclear techniques to research technology for a safe, affordable nuclear electric engine that could deliver varying levels of thrust for space applications. Nuclear electric propulsion systems may prove to be the only practical, safe, rapid method for deep-space, large-scale robotic or human exploration of Mars and the other planets. For near-term robotic exploration applications, energy from a solid-core nuclear reactor can be used to generate power for electric thrusters with specific impulses 10 to 20 times those of chemical rockets. More advanced forms of fission reactors, such as the gas core reactor, may achieve megawatt power with densities needed to shorten human trips to Mars, as well as ambitious missions beyond, to a few months.

Antimatter

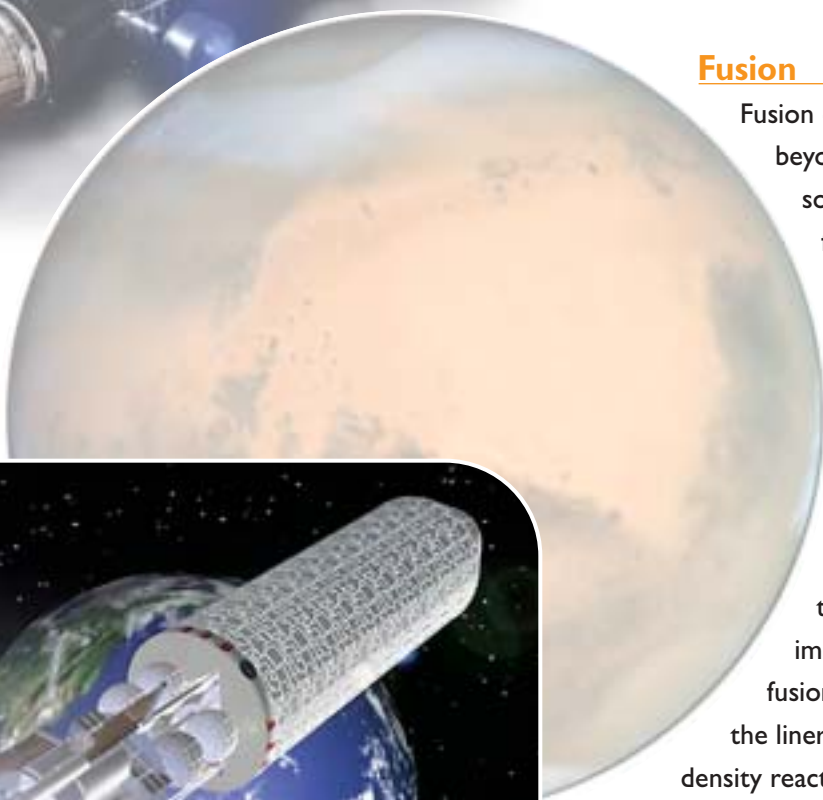
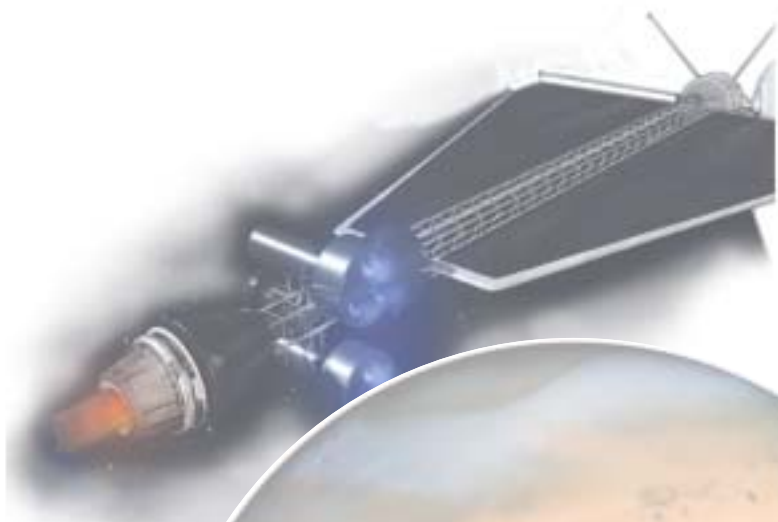
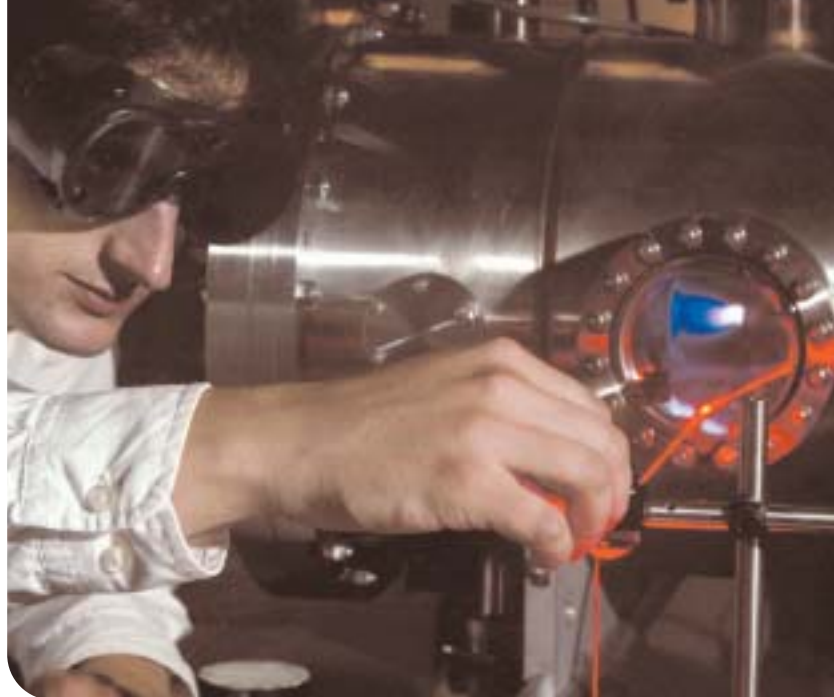
Antimatter can be thought of as a mirror image of the normal matter we see around us: the atoms' electrons and protons have the opposite charge and spin. When antimatter contacts matter, all reaction mass is quickly converted to energy. Antimatter annihilation has the highest energy release per unit mass of any reaction known in physics.

Trapping antimatter allows energy to be stored and transported at very high density, making it ideal for rocket fuel. For example, a quantity of antihydrogen the size of a raisin has an energy content equal to the total energy stored in 23 Space Shuttle external fuel tanks. Marshall has developed a high-performance antiproton trap that can “bottle” charged antimatter with magnetic and electric fields.



High-Power Plasma Propulsion

Marshall researchers are exploring the possibilities for high-power plasma propulsion. Plasma is a collection of electrons and positive ions contained in a magnetic field. Electromagnetic force accelerates and directs plasma propellant from the vehicle to produce thrust. Exhaust velocities can be 20 times greater than from conventional thermal expansion propulsion systems. Pulse plasma systems operate repetitively with capacitor banks and pulses as short as a microsecond.



Fusion

Fusion energy may enable human exploration beyond Mars to destinations in the outer solar system. Deuterium is the prime fuel for fusion propulsion and can be made from “seawater” on Earth. The challenge is to demonstrate adequate propulsive energy gain with an efficient lightweight system compared to traditional electric propulsion systems.

Marshall is investigating magnetized target fusion. The concept uses an imploding liner to compress and heat the fusion fuel that is thermally insulated from the liner by a magnetic field. A high power density reaction is expected.



Plasma Sails

The plasma sails concept involves transferring momentum from energetic plasma in space to a spacecraft through a vehicle-generated magnetic field. Leveraging the Sun's energy reduces power and consumable mass requirements. This concept also could be used to slow an approaching spacecraft so that it can enter a planet's orbit.

Solar Sails

Solar sails have been studied for a variety of missions and have the potential to provide cost-effective, propellant-free propulsion that enables longer on-station operation, increased scientific payload mass fraction, and access to previously inaccessible orbits. Marshall researchers are working on ground demonstration of a solar sail system engineering model, orbital mechanics, attitude control analytical tools, integrated solar sail diagnostics, high-fidelity computational models to assess scalability, and quantitative laboratory characterization testing of materials.



Solar Thermal Propulsion

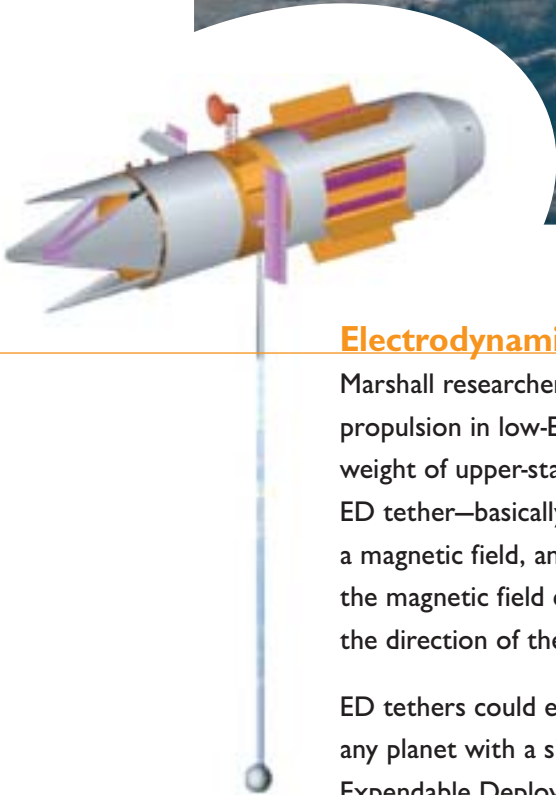
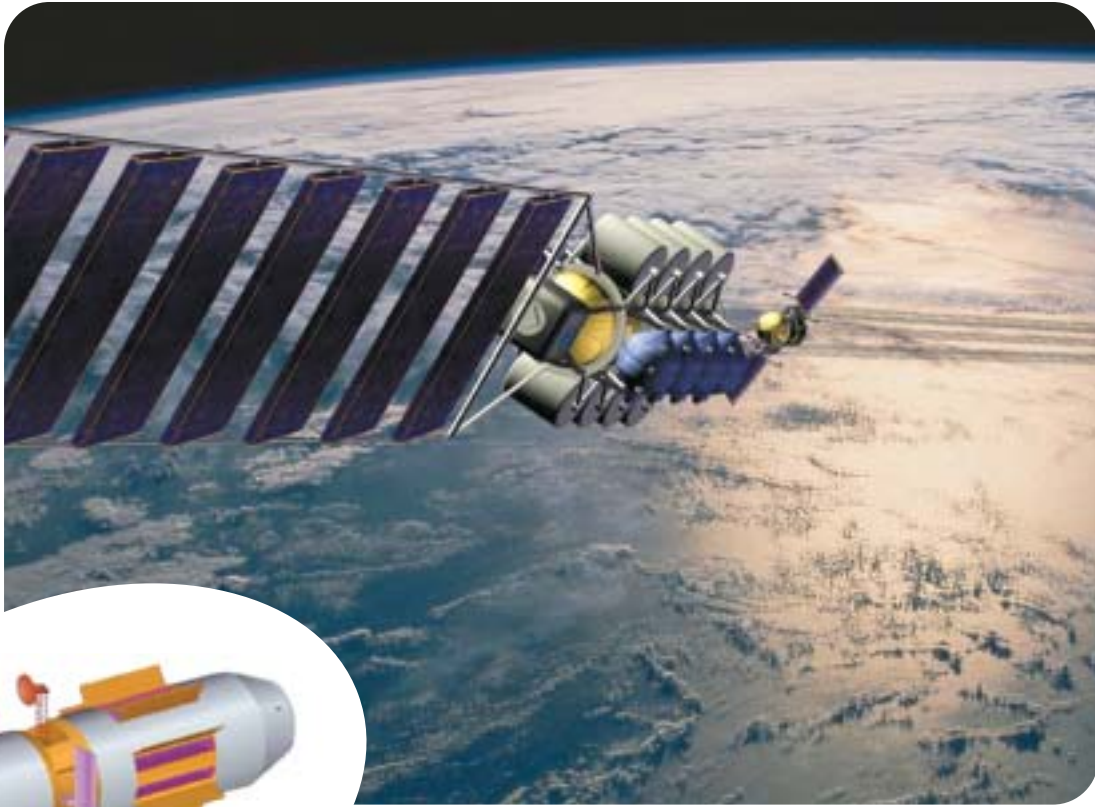
Solar thermal propulsion operates in space by capturing solar energy with inflatable concentrator mirrors that focus the sunlight inside the engine absorber cavity to heat propellant. The concept is a simple and safe method for taking spacecraft from low Earth orbit to geosynchronous orbit or Earth escape.

Marshall has developed various types of solar thermal propulsion engines and offers a unique facility capable of providing the same solar flux intensity as a location at 7 solar radii from the Sun.



Magnetohydrodynamic Propulsion

In magnetohydrodynamic (MHD) propulsion concepts, extremely high voltages passed across electrodes accelerate air flow and provide thrust. To test MHD concepts, Marshall has a 2-tesla magnet with a 4-in (10-cm) bore. When rocket engine exhaust enters the magnetic field, positive ions and negative ions are deflected in different directions. Passing these ions over electrodes builds up extremely high voltages. Marshall researchers are exploring how this concept can be used in reverse to enhance propulsion.



Electrodynamic Tethers

Marshall researchers have been studying electrodynamic (ED) tethers for propulsion in low-Earth orbit and beyond in an effort to significantly reduce the weight of upper-stage rockets used to boost spacecraft to higher orbit. When an ED tether—basically a long, thin wire deployed from a space vehicle—moves through a magnetic field, an electrical current results. The force exerted on the tether by the magnetic field can be used to raise or lower a satellite's orbit, depending on the direction of the current's flow without the use of propellant.

ED tethers could extend and enhance future scientific missions to Jupiter or any planet with a significant magnetosphere. In early 2003, the Propulsive Small Expendable Deployer System (ProSEDS) will be launched into space aboard a Delta II rocket to test the ED tether theory.

Marshall facilities used to test ED tethers include a 10^{-7} torr vacuum space plasma simulator and a 1.75-m^3 , 10^{-6} torr deployment chamber.

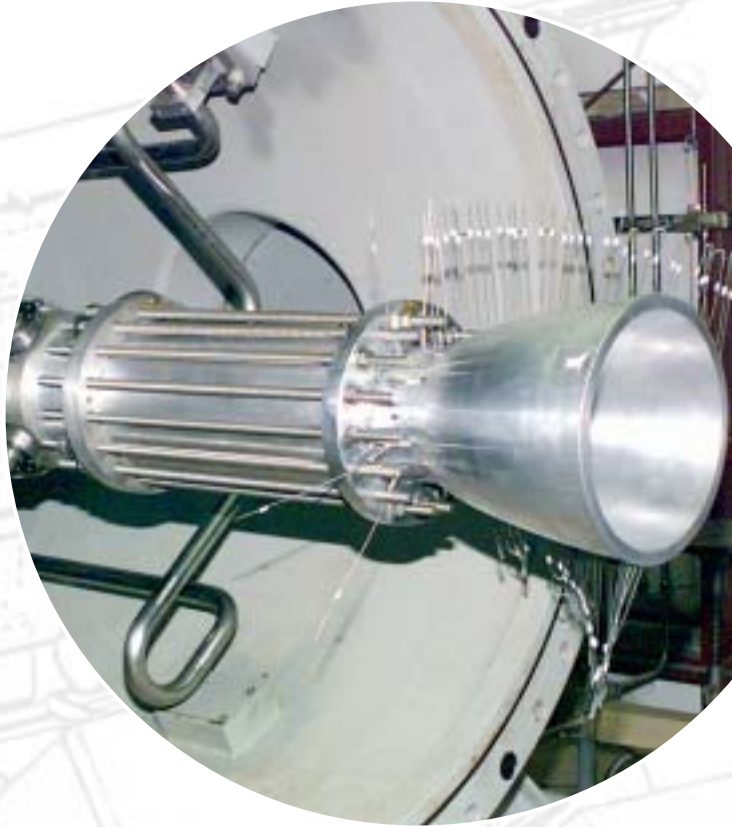


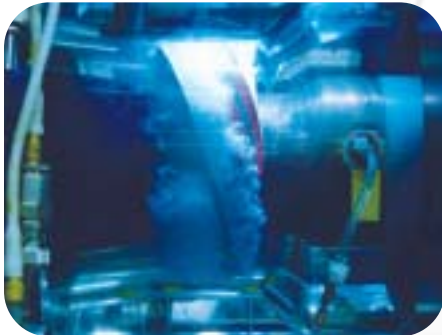
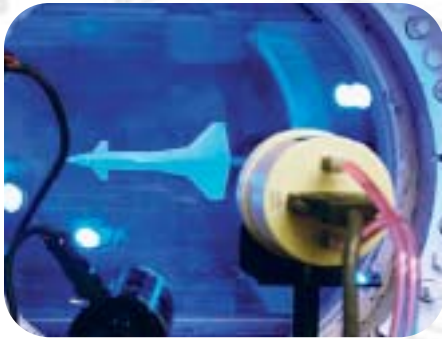
Ensuring that a launch vehicle or spacecraft will function well requires careful modeling, analysis, and design. Success in these three areas demands cutting-edge equipment, state-of-the-art facilities, and leading experts. Marshall offers all of these capabilities. Marshall welcomes U.S. industry, academia, and other government labs to utilize these capabilities to further their work in propulsion systems, engines and motors, and their subsystems.

Propulsion Systems

Modeling, analysis, and design efforts help ensure that the various elements of propulsion systems are functioning efficiently and safely. Marshall's capabilities—including customized image analysis software and photographic evaluation—can be applied to a wide range of propulsion and related systems:

- Cryogenic and hydrocarbon liquid main propulsion systems
- Hypergolic and peroxide liquid auxiliary propulsion systems
- Rocket-based combined cycle propulsion
- In-space propulsion
- Pneumatic subsystems
- Cryogenic fluid management systems





Fluid and Flow Dynamics

Aerodynamics, aerothermodynamics, acoustics, and plume environments have significant effects on propulsion systems. Marshall offers a wide range of modeling, analysis, and design capabilities to understand these internal and external influences.

- Launch vehicle aerodynamics and integration
 - Force, moment, pressure, flow, and load databases
 - Conceptual/Preliminary vehicle aerodynamic design and analysis
- Vehicle aerothermal and plume environments
 - Convection, radiation, plume induced flow separation (PIFS)
 - Ascent/Reentry aerodynamic heating
 - Protuberance heating
 - Shock interaction heating
 - RBCC thermal modeling and analysis
- Fluid dynamics and acoustics
 - Transient and steady-state fluid flow modeling
 - RBCC flowpath modeling and analysis
 - Cavitation/Flow interaction noise
 - Plume exhaust noise, sonic boom, blast loads, oscillation loads
 - Fluid/Structural interaction, instabilities
 - Ignition overpressure
- Engine dynamic data analysis
 - Engine vibration diagnostic assessment and anomaly resolution
 - Wide-band frequency assessment
 - Linear/Nonlinear phase analysis
 - Vibration analysis algorithm development
 - Specialized vibration analysis systems
 - Real-time vibration monitoring system
 - Space Shuttle main engine advanced health management system
 - High-speed data acquisition and processing systems

Other Capabilities

- Transient and steady-state thermal modeling for cryogenic storage
- Zero-G fluid storage and transfer
- Propellant systems test requirement definition and data analysis
- Water hammer analysis
- Complex mechanical design modeling

Engines and Motor Systems

Engine and motor system design involves many disciplines and core engineering functions. Performance modeling and analysis for liquid engines, hybrid motors, solid motors, and advanced engines provide designers with requirements for the early stages and assist in the evaluation of manufactured engines during test and flight. Functional design and integration activities ensure that these requirements are met and verified.

Marshall has been a leader in this area for many years and is continually updating and upgrading its design, integration, and analysis capabilities.



Performance Modeling and Analysis


- Transient and steady-state modeling
- Startup and shutdown modeling for complex liquid systems
- Test stand modeling
- Engine health management
- Maximum design condition definition and monitoring

Functional Design and Integration

- Cycle or propellant selection trade studies
- Operations, cost, safety, and reliability assessments
- Systems requirements/verification development
- Component integration
- Engine/motor-to-vehicle integration

Flight Operations Evaluations

- Assessments of motor manufacturing and quality control processes
- Flight readiness reviews, including technical evaluations of anomalies and performance trends
- Evaluation of engineering change packages



Post-Test/Flight Data Evaluation/Analysis

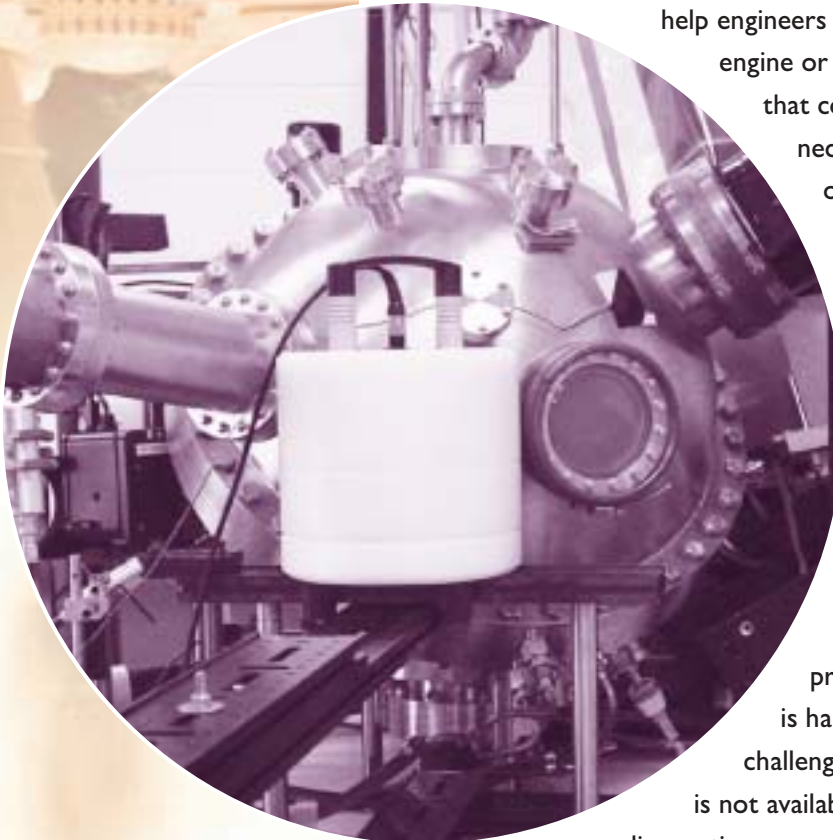
Marshall offers a world-class computer facility for processing, archiving, distributing, and analyzing propulsion test/flight data:

- Temperature
- Flow rate
- Pressure
- Vibration



Failure Analysis and Anomaly Evaluation

Marshall's fault tree and failure scenario development help engineers determine the cause of an engine or motor failure or anomaly so that corrective action can be taken, if necessary. Data are collected, organized, and used to support or refute various failure/anomaly scenarios, and recommendations for disposition are made.



Diagnostics

Many propulsion experiments require special instrumentation to more precisely validate exactly what is happening. This is extremely challenging, especially if direct contact is not available. Nonintrusive optical diagnostics can measure temperature, density, velocity, and chemical compositions. High-speed cameras can record the appearance of fast reactions. Marshall has the world's best equipment for experiment diagnostics.

Turbomachinery and Pumps

Turbines, nozzles, injectors, and other such elements must offer exceptional aerodynamic and hydrodynamic characteristics. Marshall offers extensive modeling and analysis capabilities to design superior turbomachinery and pumps. And our researchers have preeminent expertise and experience in design, development, and analysis of turbomachinery. These capabilities can benefit researchers in industry, academia, and other government labs.

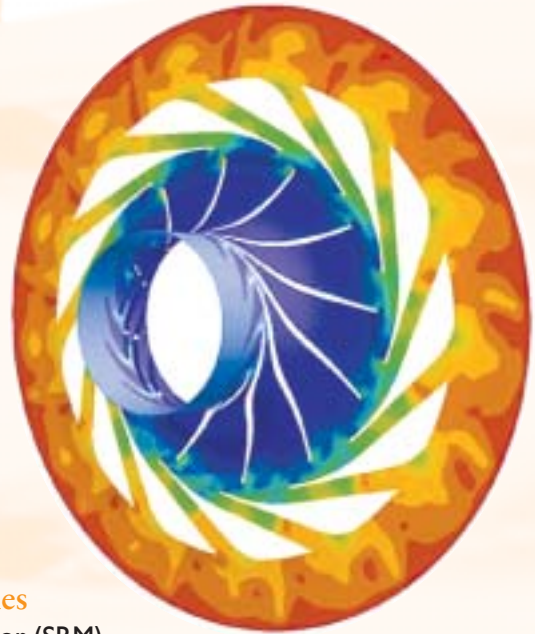


Aerodynamics

- Turbine performance and unsteady flow environment
- Nozzle performance and environments at ambient and altitude-simulated conditions
- 2-D nozzle schlieren

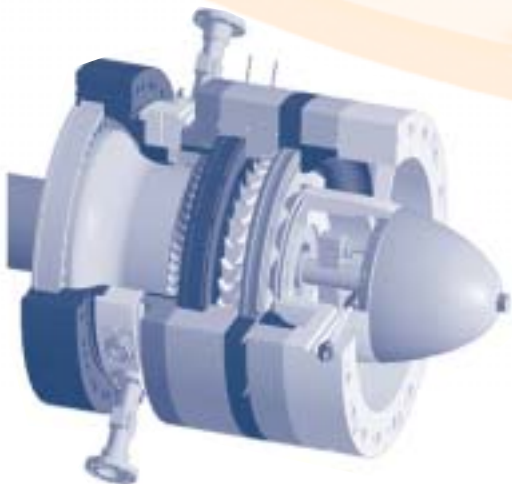
Hydrodynamics

- Inducer and impeller performance and unsteady cavitation environments
- Injector performance and mixing
- Internal flow and axial thrust analyses
- Pump stage design tools and design experience
- Cavitated and noncavitated effects
- Unsteady, time-accurate pump stage computational fluid dynamics (CFD) analysis



Other Capabilities

- Solid rocket motor (SRM) internal flow environments
Full or partial admission, hydraulic to supersonic designs
- Integrated airfoil design, geometry generation, CFD, design optimization process
- Variable-gamma CFD capability
- Application of new materials to turbomachinery designs
- Mechanical design of valves, lines, ducts, and other turbomachinery:
 - Complex turbine blades
 - Complex geometry instrumentation
 - Inducers





Combustion Devices

Marshall researchers are recognized experts in the fields of design and development of combustion devices and fully reacting, combustion-driven flows. Staff routinely perform reacting hydrogen–liquid oxygen and hydrocarbon–liquid oxygen analyses on combustion injectors, chambers, and nozzles. Mechanical design specialists undertake complex modeling of combustion devices. In addition, research is under way to apply new materials to combustion device designs to reduce weight and enhance device performance lifetime.

Industry, academic, and other government labs are encouraged to contact Marshall for assistance in designing combustion devices.

Control Systems

The sensors, actuators/effectors, software, and data systems that make up spacecraft control systems must be developed according to specific requirements.

After defining these requirements, researchers use Marshall's state-of-the-art facilities and capabilities to perform design, analysis, test, verification, and operational checkout for the control systems.

Control Mechanisms Laboratory

This world-class facility enables control mechanisms development testing for precision control mechanisms and systems. The lab has unique capabilities in the design, development, and evaluation of thrust vector control mechanisms used in launch vehicles and spacecraft.



Design and Analysis Capabilities

- Architecture definition
- Algorithm definition
- Gain determination
- Requirements specifications
- Verification requirements
- Stabilization system requirements
- Performance analysis
- Actuation subsystem functional design
- Actuation subsystem verification requirements
- Mechanical design



Operations Analysis

One of the biggest challenges for propulsion systems research is to bring down the cost of access to space. High-performance systems must minimize long-term operations costs. Such costs can be contained by designing systems that require fewer people and less equipment.

To achieve these goals, researchers at Marshall focus on the operability requirements that such systems demand. Marshall offers the capabilities to simulate how systems will operate and the cost of those operations.

Capabilities

- Turnaround time modeling
- Operations cost modeling
- Availability assessments
- Automated data mining for operations and maintenance

Marshall Space Flight Center's R&D for new propulsion systems is complemented by state-of-the-art testing equipment and facilities. From engine function to structural endurance, we have the test stands needed to ensure proper performance on the launch pad and in space. These facilities can be adapted to accommodate any test article and can be used by commercial companies or other organizations as available.

Propulsion Technology Testing

Marshall offers a variety of stands to test turbopumps, bearings, combustion chambers, and other engine elements. Feel free to contact us for more information on any of these facilities.



High-Pressure Components

Test stand 116 is ideal for testing high-pressure engine system components, turbopumps, valves, cryogenic propellant system components, and combustion devices. This multiple-position stand also can be used for environmental simulation tests. The stand features a programmable logic controller with 600 outputs to remote valves, 1,000 low-speed digital acquisition channels, 128 high-speed digital channels (250,000 samples per second), and 216 analog tape channels. The stand can run multiple tests simultaneously, saving time and propellant.

Positions

- Turbine blade position
- Acoustic model position
- Turbopump position
- Preburner position
- High-flow water position
- 60,000-lb (267-kN) thrust position

Liquid Oxygen Tests

- 3,000 gal at 5,000 psig
- Storage of 28,000 and 14,000 gal

TEA/TEB System

Liquid Hydrogen Tests

- 2,200 gal at 5,000 psig
- 2,000 gal at 8,500 psig

Gaseous Hydrogen Tests

- 1,250 ft³ at 15,000 psig
- 600 ft³ at 10,000 psig

Gaseous Nitrogen Tests

- 1,250 ft³ at 10,000 psig
- 700 ft³ at 8,000 psig

RP-1/Water Tests

- 3,000 gal at 4,750 psig
- 3,000 gal at 2,700 psig



Cryogenic/Solid Components

Test stand 500 is a six-position stand designed for hazardous testing of liquid hydrogen, liquid oxygen, solid, and hybrid propulsion components and subsystems. The bearing drive is a 500 horsepower diesel engine with a variable-speed transmission to 40,000 rpm. The recording system tracks 500 low-speed digital data acquisition channels, 31 high-speed digital channels (250,000 samples per second), and 84 multiplexed analog tape channels.

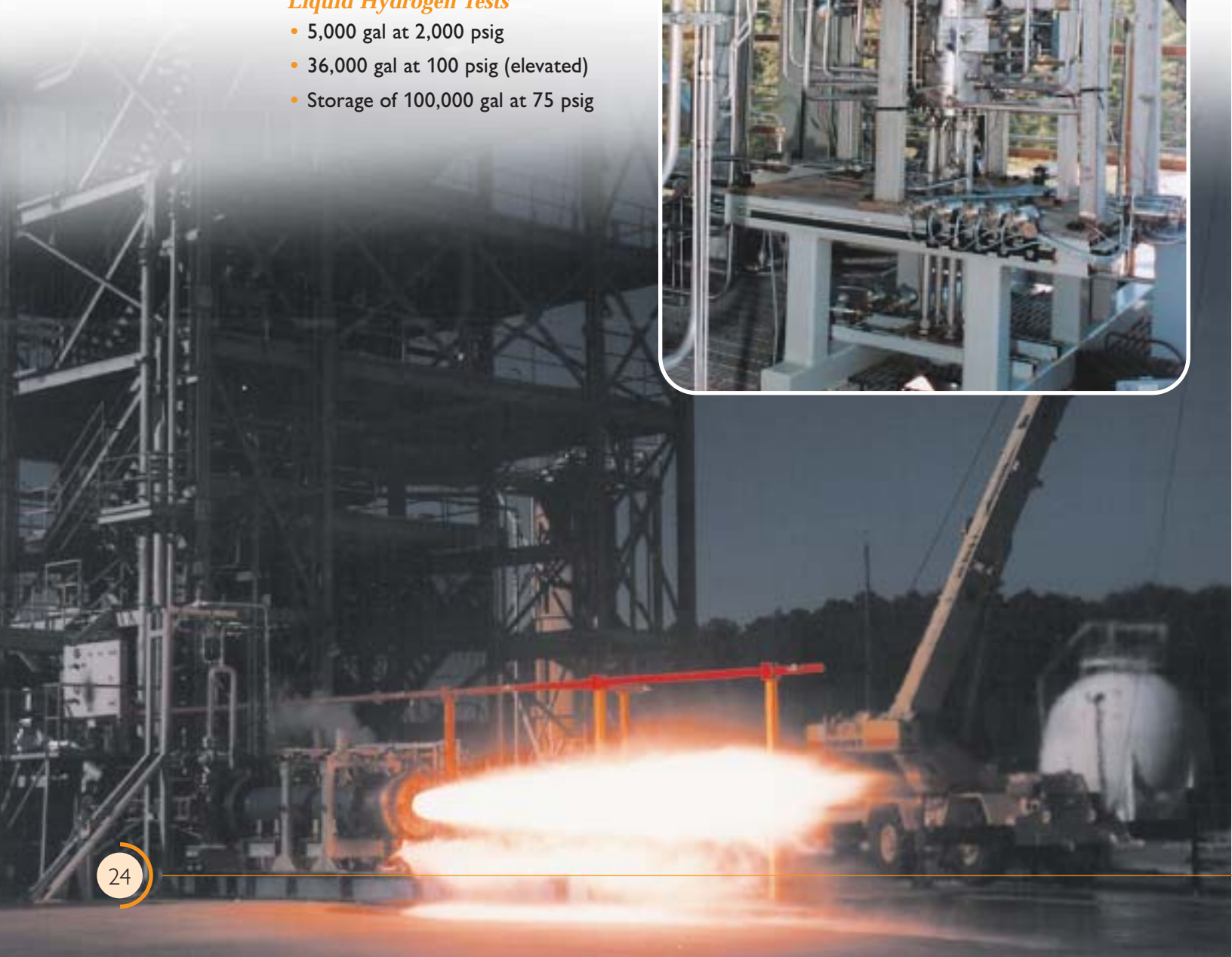
Liquid Oxygen Tests

- 3,000 gal at 2,000 psig
- 23,000 gal at 80 psig (elevated)
- Storage of 28,000 gal at 50 psig

TEA/TEB System

Liquid Hydrogen Tests

- 5,000 gal at 2,000 psig
- 36,000 gal at 100 psig (elevated)
- Storage of 100,000 gal at 75 psig



Small- and Medium-Scale Injectors

Marshall's test stand 115 and test cells are multipurpose, multiposition oxygen/hydrogen facilities for testing scale-model combustion devices and medium-pressure cold flow test articles. The test stand and cells are less expensive to run than other facilities when less propellant is required. The recording systems track either 250 or 500 low-speed digital data acquisition channels, 16 high-speed digital channels (250,000 or 1 million samples per second), and 48 analog tape channels.

Oxygen Tests

- 500 gal liquid oxygen at 3,000 psig
- 236 ft³ gaseous oxygen at 2,400 psig
- 470 ft³ gaseous oxygen at 2,400 psig

TEA/TEB System

Hydrogen/Methane Tests

- 2,200 gal liquid hydrogen/liquid methane at 1,500 psig
- 500 gal liquid hydrogen/liquid methane at 3,000 psig
- 20 gal liquid methane/rocket propellant at 3,000 psig
- 236 ft³ gaseous hydrogen at 3,800 psig

Helium Tests

- 238 ft³ gaseous helium at 4,500 psig

Nitrogen Tests

- Gaseous nitrogen at 4,200 psig
- 1-inch gaseous nitrogen facility line at 2,500 psig

Missile-Grade Air

- 1-inch facility line at 3,500 psig

Water

- 500 gal demineralized water at 3,000 psig
- Industrial water at 150 psig





Small Components

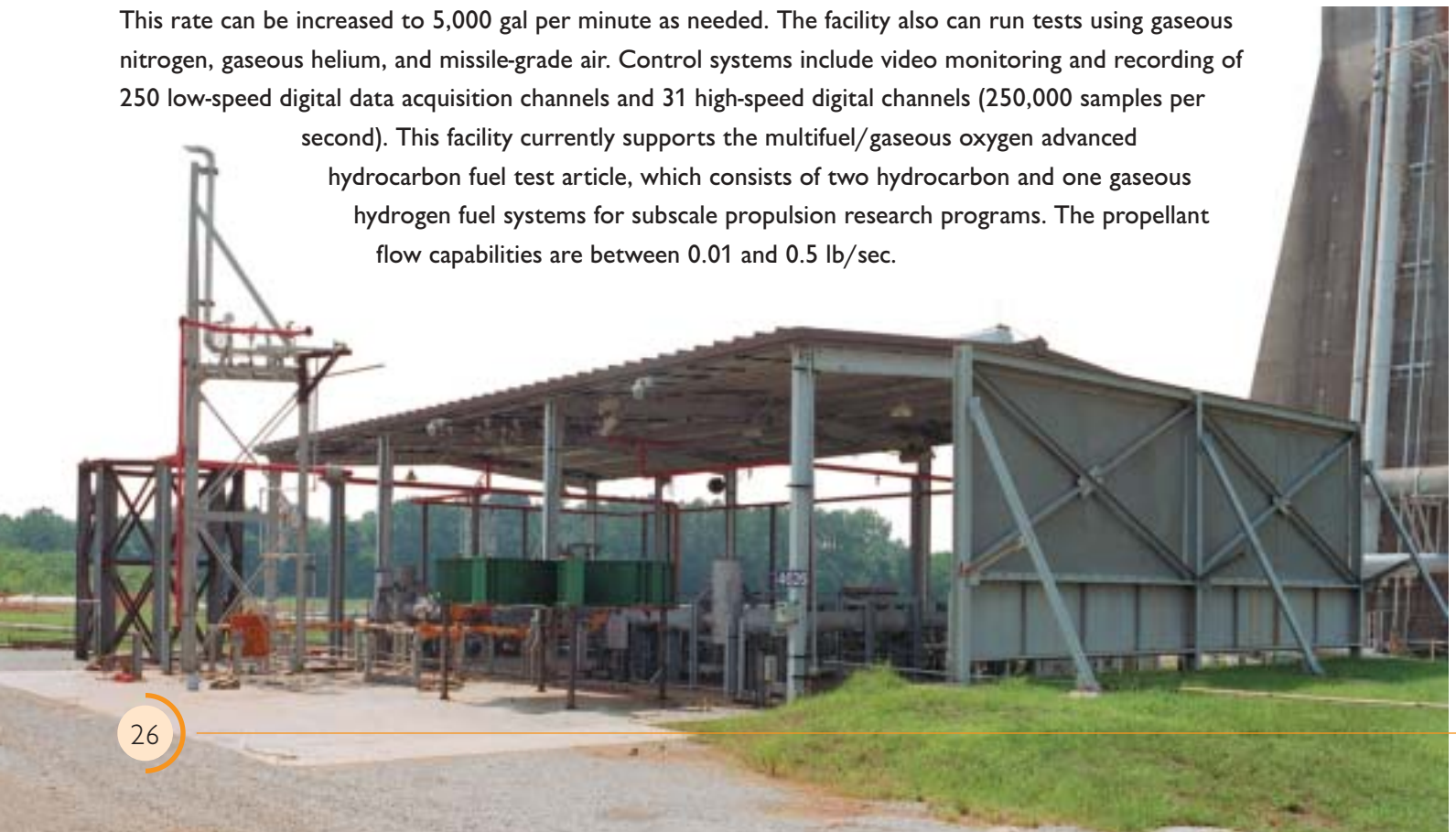
Built to evaluate and develop new component technologies to support next-generation launch vehicles, this test stand can be used to test components such as valves, ducts, flanges, and quick disconnects. The instrumentation controls pressure, flow rate, position, temperature, speed, and volume. The test stand also provides helium mass spectrometer leak detection for leaks as low as 10^{-9} cm³ per minute.

Capabilities

- Gaseous helium, nitrogen, and air at 5,000 psig
- Water and liquid nitrogen at 5,000 psig
- Hydraulic fluids at 3,000 psig
- Temperatures ranging from +450 to -320 °F
- Flow rates up to 100 gal per minute for liquids and 10,000 ft³ per minute for gases
- Vacuum level: 10^{-6} torr
- Data and control system provides 68 configurable channels
- Video recording can be synchronized with data
- Near real-time data acquisition via the Internet

Hydrogen Cold Flow Facility

This low-pressure, low-flow-rate system tests hydrogen engine and subsystem components. The facility can accommodate test articles up to 20 by 20 by 15 ft (6 by 6 by 4.5 m) in size. Liquid hydrogen flows from one 225,000-gal tank through the test article into a second tank at a rate of 1,800 gal per minute. This rate can be increased to 5,000 gal per minute as needed. The facility also can run tests using gaseous nitrogen, gaseous helium, and missile-grade air. Control systems include video monitoring and recording of 250 low-speed digital data acquisition channels and 31 high-speed digital channels (250,000 samples per second). This facility currently supports the multifuel/gaseous oxygen advanced hydrocarbon fuel test article, which consists of two hydrocarbon and one gaseous hydrogen fuel systems for subscale propulsion research programs. The propellant flow capabilities are between 0.01 and 0.5 lb/sec.





S1C Large Engine/Stage Test Facility

Designed for testing the Saturn V vehicle, this facility can withstand 12 million lbs of vertical thrust, and thrust levels can be upgraded with relative ease. Two test positions are pressurized with gaseous nitrogen and gaseous helium.

Control and instrumentation systems have been updated to a highly flexible, integrated data and control system that is capable of providing real-time graphical data and model verification. The data system is expandable in a building-block type arrangement with current capabilities of 750 channels of digital data (maximum record speed of 100 s/s) and 200 channels of analog data.

Liquid Hydrogen

- 75,000 gal at 50 psig

Liquid Oxygen

- 23,000 gal at 150 psig
- 12,000 gal at 130 psig

RP-1

- 6,000 gal at 130 psig

Structural Testing

The structural integrity of fuel tanks and other propulsion components must be verified and maintained to ensure successful space flight missions. Marshall offers several structural test facilities. For more information about any of these facilities, please contact us.

Quasi-Static Testing

Marshall's quasi-static testing facilities can be used to conduct full-scale reaction load and hydraulic testing of large structures—up to 60 ft (18 m) in diameter.



Capabilities

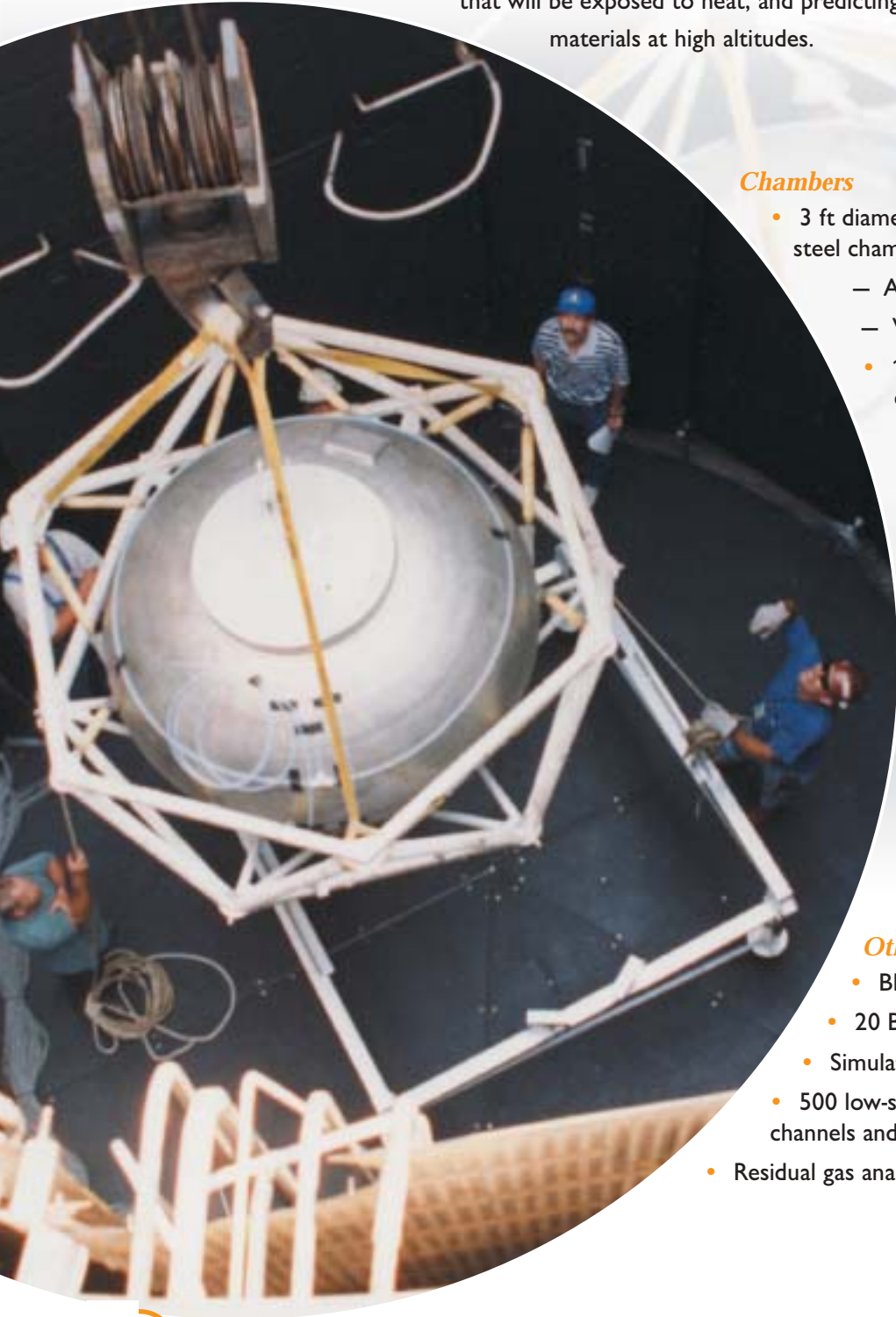
- Compression loads up to 33 million lbs (147,000 kN)
- Tension loads up to 3 million lbs (13,300 kN)
- Pressure measurement
- Contourable photoelastic coatings for strain and temperature testing
- Hazardous testing in pressurized, cryogenic, liquid hydrogen, and nitrogen environments

Cryo-Structural Testing

Marshall's cryogenic fluid transfer system is ideal for testing the soundness of smaller structures. Based on a 30-by-30-ft (9-by-9-m) concrete test pad measuring 2 ft (60 cm) thick, the system offers cryogenic testing using liquid hydrogen and nitrogen and various gases, including hydrogen, nitrogen, helium, and missile-grade air, at 150 psig. Compression and shear load testing capabilities also are available in this facility. Control systems include video monitoring and recording of 250 low-speed digital data acquisition channels.

Thermal Vacuum Testing

This facility is used to conduct hazardous tests using cryogenics and heat loads to simulate liftoff, pressure ascent, and deep space profiles. These tests are useful for developing insulation for external fuel tanks, screening composite materials that will be exposed to heat, and predicting the performance of materials at high altitudes.



Chambers

- 3 ft diameter by 3 ft tall (1 m by 1 m) stainless steel chamber
 - Ambient temperatures
 - Vacuum level: 10^{-6} torr
- 12 ft diameter by 14 ft long (3 m by 4 m) carbon steel chamber
 - Elevated temperatures (e.g., radiant lamp testing of insulation materials)
 - Vacuum level: 1.0 torr
- 15 ft diameter by 15 ft tall (4.5 m by 4.5 m) stainless steel chamber
 - Deep space temperatures; liquid nitrogen cold wall available
 - Vacuum level: 10^{-3} torr
- 20 ft diameter by 35 ft tall (6 m by 10 m) stainless steel chamber
 - Deep space temperatures; liquid nitrogen cold wall available
 - Vacuum level: 10^{-7} torr

Other Features

- Blast environment wave simulator
- 20 BTU/ft²/sec radiant heat loads
- Simulation runs up to 40 days
- 500 low-speed digital data acquisition channels and 96 analog tape channels
- Residual gas analyzer

Marshall also offers other facilities to study structural and flow dynamics



Structural Dynamics

- Vibration and vibroacoustics
- Pyrotechnics
- Modal testing

Flow Dynamics

- Aerodynamics
- Water flow
- Air flow
- Heat flow



These facilities are described in greater detail in Marshall's Aerospace book in this series.



Technology Transfer at Marshall

This information package has been assembled as part of NASA Marshall Space Flight Center's technology transfer program.

The primary goal of the technology transfer process at Marshall is to encourage broader utilization of Marshall-developed technologies and our unique combination of facilities in the U.S. industrial communities.

We invite you to contact Marshall to discuss possible partnership opportunities and availability of facilities.

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